[0054] As described above, embodiments of the present invention measure the received signal characteristics/channel information (of the low-frequency bands) to predict whether the conditions of the high-frequency bands are favorable for offloading communication from the low-frequency bands to the high-frequency bands. In one embodiment, the measurements for the received signal characteristics/channel information can be used to infer/predict a path-loss in the higher frequencies. A lower path-loss tends to indicate that the offloading is feasible. Further, the received signal characteristics/channel information can be used to predict LOS channel availability within the higher-frequencies. As described above, an LOS channel may be necessary for the offloading to occur.

[0055] FIG. 1 illustrates received signal power versus link characteristics in accordance with embodiments of the invention. Referring to FIG. 1, the x-axis displays several received power intervals assuming 0 dBm (1 mW) transmit power. This received power can be considered to be values of RSSI. The simulation results of FIG. 1 show that higher RSSI values (received in the lower-frequency bands) will generally result in a higher likelihood that an LOS is present in the higher-frequency bands. The correlation between the LOS condition and high RSSI is evident from the fact that the probability of LOS becomes larger when RSSI increases. Specifically, when RSSI increases to the largest RSSI range, the probability value reflected by "LOS" is higher than the value reflected by "NLOS".

[0056] FIG. 1 illustrates a correlation between RSSI and the likelihood that an LOS is available. In addition to using RSSI measurements, other embodiments can use other measurements to ascertain whether offloading traffic to the higher-frequency channels/bands is feasible. For example, another embodiment can also use a proportion of CIR energy (such as a proportion of CIR energy in a first tap), and/or a delay indicator (such as an RMS value of the delay spread) to perform LOS channel prediction. As described above, the proportion of channel impulse response (CIR) energy in the first tap can correspond to the amount of energy received in the first tap (for example, received by a UE) compared to the total amount of energy received in all the taps. The proportion can generally be calculated using equation 1 below:

$$X = \text{(Power of the first tap)}/\text{(Sum of power of all received taps)} \qquad (1$$

[0057] As described above, if a greater proportion of energy is received in the first tap as compared to the other subsequent taps, then there is a higher likelihood that propagation conditions in the high-frequency channels/bands are favorable for offloading communication to the high-frequency channels/bands.

[0058] In another embodiment, a classifier can be used to analyze one or more signal/channel characteristics to determine whether LOS conditions exist or not. Another embodiment can use a plurality of classifiers to analyze a plurality of signal/channel characteristics. In one embodiment, a linear discriminant analysis (LDA) classifier, described in R. A. Fisher: "The Use of Multiple Measurements in Taxonomic Problems" in Annals of Eugenics 7 (2): 179-188, can be used to analyze signal/channel characteristics such as RSSI, RMS delay spread, and/or ratio of CIR power in the first tap of the CIR, as in equation (1). Other types of classifiers may be also utilized. In some embodiments, the classifier may produce a likelihood of favorable conditions for communication on high frequency resources.

[0059] One embodiment performs a plurality of observations for each link of the low-frequency channel. For example, one embodiment can perform three observations to be used as an input to the classifier. Of the three observations for each link, one observation can be a received power (for example, in milliWatts). Another observation can be an RMS delay spread (for example, in microseconds). Another observation can be the ratio of CIR power in the first tap of the CIR, as in equation (1) (for example, in milliWatts). In some embodiments, these observations may be obtained from estimating the channel characteristics utilizing the reference signals transmitted and received on the low-frequency channel.

[0060] Further, one embodiment of the present invention can apply a linear classifier to the data. One example of a linear classifier is a linear discriminant analysis (LDA) classifier. One embodiment transforms the data so it is closer to being Gaussian distributed by taking a logarithm of the RMS delay spread and received power.

[0061] By using the above embodiments, LOS and NLOS can be predicted accurately. In some instances, a detection probability of NLOS conditions can be 97.5%. In other words, with such a classifier, if a decision is made to not scan a high-frequency band (such as an mmW band) because a NLOS condition appears to be prevailing, the decision is wrong only 2.5% of the time. Such an observation is based on channel models (such as a WINNER phase II spatial channel model, described in document IST-WINNER D1.1.2 by P. Kyösti, et al.: "WINNER II Channel Models", ver 1.1, Sept. 2007), which is based on extensive field measurements.

[0062] However, in circumstances where a classifier is not able to accurately ascertain LOS and NLOS conditions, the classifier may be improved/re-trained to more accurately infer the conditions of the high-frequency bands (such as the mmW bands). In a multi-antenna array eNB, each resolvable channel path (tap) has its spatial correlation value available (which may be called the spatial signature of the path). The spatial signature contains the relative phase and amplitude of the received path at each of the multiple antenna elements. When the eNB starts logging the measured mmW channel quality versus these CIR/delay/RSSII/spatial correlation observations, it can learn when the mmW connection may be established. This way, although measurements of the high-frequency channels are monitored/measured frequently in the beginning, in the long-run the monitoring/measurements performed can be much less (as the eNB learns the environment in which it is deployed). In some embodiments, the learning may comprise updating a classifier such as, for example, the LDA classifier.

[0063] Other embodiments can perform other types of measurements. Other types of measurements may include measurements relating to the spatial signature of each resolvable path (or a transformation thereof such as the direction of arrival estimate). Such a measurement is possible, for example, when a base station transceiver is equipped with multiple antennas. Furthermore, the direction of arrival estimates may be utilized in combination with estimates of the geographic location of a user equipment.

[0064] FIG. 2 illustrates a logic flow diagram of a method according to certain embodiments of the invention. An exemplary flow-chart for the proposed method (to dynamically tune the high-frequency component carrier measurement occurrence) is given in FIG. 2.

[0065] As shown in FIG. 2, a classifier output value, which takes one of a plurality of output values, can be used to